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Computerized Hand-held Instructional Prototype (CHIP): Final Report

V. Melissa Holland and Robert A. Wisher
U.S. Army Research Institute

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This report describes the development and evaluation of the Computerized Hand-held Instructional Prototype (CHIP). CHIP is a self-contained and fully portable, battery-operated training device small and light enough to be hand-held during operation. The report describes the CHIP and its software, and summarizes five applications in the Army, Navy, and Air Force. CHIP produces the best results when used as a voluntary trainer to supplement lectures and practical exercises outside the classroom. Recommendations for the use of CHIP in schoolhouse exercises and in the field are included.

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Computerized Hand-held Instructional Prototype (CHIP): Final Report

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To ensure that the U.S. Army's soldiers acquire the skills and knowledge necessary to perform their jobs successfully, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) performs behavioral research to develop methods of training that can improve skill acquisition. This goal is shared with the other services. Within the ARI Training Research Laboratory, the Development Engineering Office (DEO) provides management oversight for applied research on prototype development and evaluation of a product by two or more services as part of the Joint Services Manpower and Training Technology Development Program.

This summary report of the Computerized Hand-held Instructional Prototype (CHIP) was prepared by the DEO in cooperation with the Technologies for Skill Acquisition and Retention Technical Area. The results of this work provide the Army and other services the functional requirements for developing a training aid that is inexpensive, portable, and effective.

EDGAR M. JOHNSON
Technical Director

COMPUTERIZED HAND-HELD INSTRUCTIONAL PROTOTYPE (CHIP):   FINAL REPORT

EXECUTIVE SUMMARY

Requirement:

A training device needs statement was prepared by the U.S. Army Air Defense Artillery School, Fort Bliss, Texas, to develop a hand-held training aid that could easily be carried into the field and distributed to units during lull periods. The development of the device stemmed in part from a successful demonstration of a hand-held vocabulary tutor previously developed by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). The Navy and Air Force expressed an interest in developing the Computerized Hand-held Instructional Prototype, or CHIP training technology in a coordinated manner, resulting in a joint services approach.

Procedure:

As the lead service, ARI further developed the vocabulary tutor by updating the electronics, expanding the instructional routines beyond vocabulary training, improving aspects of the human factors design, adapting for field use, and coordinating the development of training applications and the evaluations across the services. Five applications were developed: two for the Army and one each for the Navy, Air Force, and an interservice school. The evaluation tested CHIP as used in initial supplemental, remedial, and refresher training at six sites. The training effectiveness of CHIP was contrasted with various training alternatives and conditions of use.

Findings:

CHIP produced the best results when used as a voluntary trainer to supplement lecture and practical exercises during lull time outside the classroom. Under classroom or study hall conditions, when the alternative is an instructor providing lecture and tutoring, CHIP trained no better and in some cases, not as well as the training alternative. CHIP also produced the best results when used by subject matter novices who receive their primary introduction to the subject by instructors. CHIP worked best for topics requiring memorization of facts and terms, quick identification of auditory patterns and visual features, and fluency in simple math, physics, or engineering facts and formulas.

Utilization of Findings:

These findings, along with the functional specifications, instructor guide, and human factors evaluation, can serve as the basis for the device specified in the training device needs statement. Some users who participated in the evaluation are continuing to use the prototypes. A technology transfer agreement is under negotiation to commercialize the product for public use.

COMPUTERIZED HAND-HELD INSTRUCTIONAL PROTOTYPE (CHIP): FINAL REPORT

CONTENTS

COMPUTERIZED HAND-HELD INSTRUCTIONAL PROTOTYPE (CHIP): FINAL REPORT

INTRODUCTION

The purpose of this report is to account for the development and evaluation of the Computerized Hand-held Instructional Prototype, or CHIP. The effort was an undertaking of the Joint Services Manpower and Training Technology Development (JS/MTTD) program from October 1984, when funding first became available, through October 1988, when the final evaluation summary was delivered. Funds for the field evaluation were supplemented by the Air Force and by the Army Air Defense Artillery School. This report traces the development of CHIP from its antecedent technology, the Hand-Held Tutor, through its contractual development, coordination across the services, field evaluation, distribution of prototypes, and plans for commercialization through a formal technology transfer agreement.

The focus of the report is twofold: a description of the CHIP device and its software (under "Product Description") and a summary of the results of an evaluation of training effectiveness (under "Test and Evaluation"). The evaluation involves a series of six applications with five of the six summarized here. The sixth and final evaluation, at the Explosive Ordnance Disposal (EOD) School, Indian Head Naval Ordnance Station, Maryland, is summarized in a separate report.

Each of the five completed evaluations is discussed in terms of its procedures and findings. Overall conclusions are derived from these findings, and recommendations are provided for the utilization of CHIP. Detailed descriptions of procedures and results may be found in the separate evaluation reports provided by each CHIP application.

The CHIP functional specifications (Technology Inc., 1985a) give the details of software design. A companion report (Technology Inc., 1985b) presents details on the CHIP hardware. A courseware selection and development guide has been published (Oxford, Holland, and Goble, 1987), and an instructor's guide is available through ARI.

BACKGROUND

The development of CHIP stemmed in part from a successful demonstration of an earlier computer-based training aid. This training aid, the Hand-Held Tutor, or simply Tutor, was developed by the Army Research Institute (ARI) between 1981 and 1984, as part of a research program in basic skills (Simutis, Ward, Harman, Farr, and Kern 1988). The Tutor was designed initially to train technical vocabulary related to the operation of a weapon system.

A contract was awarded to the Franklin Research Center in September, 1981, to design and produce twenty prototype Tutors for instruction on one hundred twenty-four (124) words or short phrases related to the operation of a field artillery piece, MOS 13B. An evaluation of the Tutor used by cannon crewmen during a field training exercise (Wisher, 1987) demonstrated that soldiers who used the Tutor were more likely to complete the twenty instructional units than were a comparable group using a workbook. For those soldiers completing the instruction, the Tutor group also demonstrated a nearly two to one improvement

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in word knowledge when compared to the workbook group. The field evaluation demonstrated that soldiers were able to make profitable use of a hand-held training aid, particularly during lull periods such as troop movement or down times. The success of the Tutor prompted users to realize some advantages of hand-held training technologies for field use.

To make use of lull time for training purposes requires devices that are highly affordable, are small and portable enough to be carried into the field and to be distributed easily to units, and are reasonably rugged to withstand use in a field environment. The requirement for a computer-based training device that is portable enough for lull time use was written by the U.S. Army Air Defense Artillery School (USAADASCH). This requirement appeared as a Training Device Needs Statement (draft in October 1986). The Navy and Air Force expressed an interest in further developing this training technology in a coordinated manner. As the lead service, the Army, through ARI, proposed to develop further the Tutor technology, and was funded through the JS/MTTD program under program element 64722A to develop CHIP. The plan for development was to update the electronics, expand the instructional routines beyond vocabulary training, improve aspects of the human factors design, adapt for field use, and coordinate the development of training applications and the evaluation of CHIP among the three services.

A procurement action was prepared in October 1984, for a competition which was announced in the Commerce Business Daily in March 1985. An award was made to Technology, Incorporated in June, 1985, for the development of a hand-held training aid. In the meantime, a working group with representatives from the Army, Navy, and Air Force was formed. The purpose of this group was to assist in providing Government-furnished information to the contractor for developing service-specific training applications; reviewing pertinent contract deliverables; and coordinating the evaluation of CHIP within their respective services. The Contracting Officer appointed researchers from ARI to serve as the Contracting Officer's Representatives.

Design decision and key milestone reviews were conducted throughout the course of the development contract. These reviews served as a tool to ARI in assessing the technical, schedule, and cost performance of the contractor. The reviews also provided a systematic means for the other services, through their working group representative, to influence the course of CHIP development and evaluation. The principal design decision review occurred as part of an In-Process Review in November, 1985. Key milestone reviews occurred as briefings to the Joint Service Committee that sponsored CHIP. The milestone of completing the development of CHIP with courseware applications was achieved in July, 1986. The user evaluation of CHIP began in August, 1986, with the fifth test application completed in December, 1987. The final summary and integration of test results was delivered in October, 1988.

PRODUCT DESCRIPTION

This section describes the physical configuration of CHIP, its generic software, and its specific courseware applications.

Overview

CHIP is a self-contained and fully portable, battery-powered training device small and light enough to be hand-held during operation (see Figure 1). It presents instruction to supplement or to sustain classroom training. Designed mainly for use in the field, CHIP is the size of a three-ring binder and weighs six pounds without its attached booklet. Synthesized voice, special audio-visual effects, and instructional routines that include arcade-like games, are used to enhance the effectiveness of training and motivate the student. A cost goal of under $200 per unit has been established for quantity buys.

A removable courseware cartridge, which inserts into the back of the device, provides curriculum flexibility for various technical specialties. Accompanying booklets, stored in a protective lid, contain explanatory material and illustrations related to the specialty. The illustrations provide inexpensive, high-quality graphics to supplement screen displays. Questions may be printed in the book, displayed on the screen, or spoken by the CHIP's voice synthesizer. The user responds by pressing keys, mostly with the thumbs, on a special keyboard designed to facilitate heads-up operation.
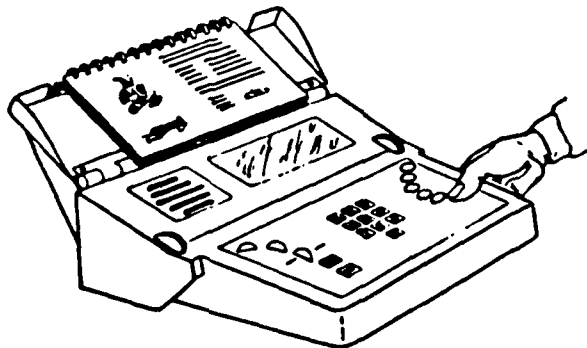

Figure 1. Computerized Hand-held Instructional Prototype (CHIP): Open Position

Design Rationale

The basic philosophy behind the development of CHIP is that learning will be more likely to occur if it is made more interesting and more convenient. CHIP attempts to make learning more interesting than traditional media such as workbooks by talking to students, interacting with them, and providing videoarcade-like feedback. It utilizes several different instructional routines employing state-of-the-art training principles from cognitive psychology.

CHIP attempts to make learning more convenient than conventional computer-assisted instruction being battery-powered, portable, and hand-held. These features allow it to be easily transported to and used in nontraditional learning environments.

The validity of these concepts was demonstrated in the hand-held Tutor. In progressing from the Tutor prototype to CHIP, an attempt was made to capitalize on and further enhance the features of Tutor that contributed most to its effectiveness--its portability, convenience, audiovisual capability, and gaming approach. It was also given some additional capabilities. The Tutor was designed mainly to provide job-related vocabulary training, whereas CHIP also provides job-related procedural training. Also, the Tutor had a one-line display and a single gaming feature, which necessarily was somewhat simple but nonetheless generated high interest. CHIP employs an eight-line display and three different gaming features with more sophisticated graphics and audio effects.

CHIP was designed so that a considerable amount of corrective feedback occurs within a game Format. Gaming features, if they are effective, may enhance learning in a straightforward way, by increasing the amount of time that is spent on the training task. Time on task is a potent variable in a variety of situations (Denham & Lieberman, 1980). It is important not only in the laboratory but also in classrooms (Stallings, 1980) and in training operational procedures (Knerr, Harris, O'Brian, Sticha, & Goldberg, 1984).

Physical Configuration

CHIP's external design was determined by human factors principles. In addition to CHIP's small size and shape, the geometry of the response keys, controls, and indicators is optimized to facilitate heads-up operation. For example, sculpted grips on the sides of the device comfortably position the user's hands near the keyboard.

The audiovisual area slopes up from the keyboard area to provide an optimum viewing angle of approximately 22 degrees (MIL-STD-1472C, 1981). The audio and video controls and the most frequently used input keys are arranged so that they can be operated by the thumb while CHIP is held in the hands, allowing users to keep their eyes on the screen.

Lid, Bookrest, and Book

A hinged plastic lid, when closed, provides protection for CHIP's controls and storage for the book and for an earphone, and when folded back serves as a sturdy bookrest, with the book already in place. When stowed, the book lies over the keyboard, providing extra padding for protection. When the lid is folded back and secured, the book's rigid cover fits into a pocket that secures the book directly above the display screen in approximately the same visual plane as the display screen (See Figure 1).

Pages are flipped upward over the top as they are completed rather than side-ways to the left, minimizing the likelihood of the wind accidentally turning pages when CHIP is used outdoors. (Pages are printed on both sides, but only the front side of each page is used during the first half of a course. Midway through the course, the student turns the book over, and uses only the back side of each page for the remainder of the course.) Pages are be 8.5 by 4.67 inches, or one-third of a standard legal-size sheet of paper, to enable easy reproduction of additional copies on standard photo-copying machines. Pages are bound with commonly available plastic ring binders.

Audiovisual Controls and Indicators

The speaker and display screen are positioned side by side to make combined audiovisual outputs emanate from the same general area. The display screen is a Hitachi LM200 liquid crystal display using 5X7 dot matrix characters. The eight-line, 40-column screen allows simultaneous multi-line text display and facilitates arcade type gaming features. A thumbwheel control to optimize video contrast for various viewing angles is positioned on the right side, and a thumbwheel ON-OFF/Volume control is positioned on the left side near the speaker, for easy access without interfering with hand grip. A 2.25 inch speaker was chosen for optimum fidelity of the digitized audio.

The miniature earphone jack is positioned on the left side near the front—on the side so it will not rub against the student's abdomen when CHIP is held in the lap, and near the front so the cord will not interfere with hand grip or get tangled in fingers.

Keyboard (see Figure 2)

Keys are arranged to facilitate heads-up operation and maximize use of thumbs in responding. Informal tests on a mockup showed that students find it more convenient to activate keys with their thumbs rather than their fingers when operating a hand-held device. The less attention students have to devote to finding the right keys, the more attention they can devote to the screen and the book. Use of thumbs also makes CHIP seem more like a familiar arcade device and less like a typewriter keyboard or computer terminal.

CHIP uses an environmentally protected touch panel (Microswitch membrane panel) as a keyboard. Embossed borders on touch pads enable positive finger positioning. Snap disc keys provide tactile feedback of switching action. An adhesive seal bonds the touch panel to the CHIP housing. Mass termination to connector provides a microcontroller-compatible connection.

The A-B-C-D-E keys, used extensively in responding to multiple-choice questions, are laid out in an arc on the right side so they can be pressed by thumb while gripping the CHIP. An embossed dimple on the middle (C) key, helps the student verify tactilely that the thumb is in the center position.

Placement of the A-E keys in an arc is desirable because it allows the user to move the thumb from key to key, following the natural arc of the thumbswing, without having to shift handgrip. The radius and focus of the arc were calculated based on available 5th/95th percentile norms (NASA, 1978; MIL-STD-1472C, 1981) and were demonstrated to be adequate through informal testing.

Placement of the A-E keys along the right side is desirable for two reasons: (1) These are the most critical and frequently used keys, and the majority of users, about 92% will have greater dexterity with their right hand. (2) The majority of users also will have greater strength with their right hand, and would prefer to use their right hand to support CHIP while turning pages with their left hand; if the A-E keys were on the left side, users would have to reorient their thumb in relation to the keys after each turn of the page, whereas with the keys on the right side, the thumb can remain in place.

The five YES, NO, GO, ERASE, and SAY special-function keys are similarly but not identically arranged on the left side, with the GO key also identified tactilely with an embossed dimple so they too can be pressed by the thumb while gripping the CHIP. They also have distinctive shapes and colors, as well as labels, to aid in quick identification of function.
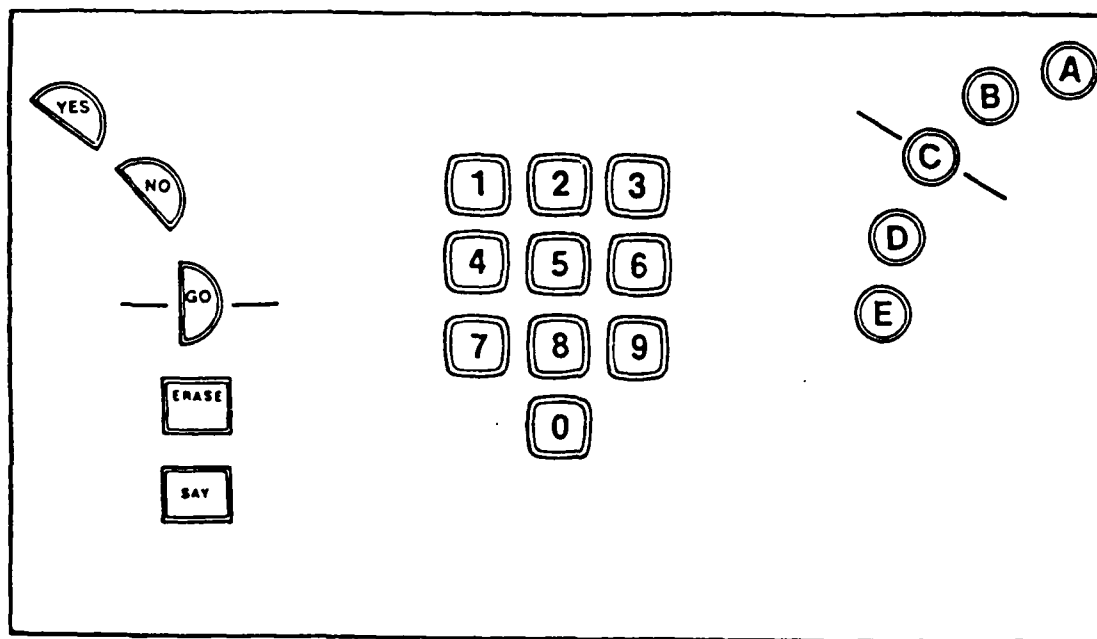

Figure 2. CHIP Keyboard Layout

Less frequently used numerical keys are arranged in a 3X3X1 pattern, similar to the telephone touch-tone pad, in the center of the keyboard. It is still possible, but not as convenient, to operate these keys while holding CHIP with the other hand.

Electronics Design

CHIP's main printed circuit board (PCB) contains a microcontroller, memory, logic, speech, and driver circuits. The removable courseware cartridge has smaller printed circuit board, which is enclosed in a sturdy plastic housing for protection. To enable the longest possible operating time without battery recharge or replacement, Complimentary Metal Oxide Semiconductor (CMOS) technology is used in all electronic components except for the speech chip, which is N-channel type Metal Oxide Semiconductor (NMOS). CHIP is powered by four or eight removable D-size batteries, and can operate for up to 50 hours without replacement.

The microcontroller, an Intel 80C31, has externally programmable read-only memory (ROM) rather than built-in program ROM. This allows for easy exchange of programs. The 80C31 directly addresses 64K bytes of external program memory and 64K bytes of external data memory, with a paging scheme to extend the address space.

Speech is generated by a General Instruments SP1000 speech synthesizer. Words, phrases, and special sound effects are developed initially off-line on a cassette tape recorder. The analog audio is then fed to a speech digitizer that is part of a special MS DOS-based CHIP courseware authoring program. The digitized audio is compressed at a ratio averaging 3000 bits per second, then downloaded into programmable ROMs for installation in the CHIP courseware cartridge. Non-volatile RAM memory enables records to be uploaded via an RS-232 communication port to a microcomputer for detailed analysis.

The memory on the main PCB contains display, speech, and instructions common to all training, plus the non-volatile student record-keeping memory. The non-volatile RAM memory is an 8K byte Dallas Semiconductor DS1225 that uses an internal lithium energy source to maintain the data when power is turned off.

The courseware cartridge memory contains display, speech, and instructions unique to a particular course subject. The board has provisions for up to twelve 32K byte programmable ROMs, or 384K bytes total, to be used as needed for specific applications.

Instructional Software

Instructional Routines

CHIP has four generic instructional routines that are operative for any specific training application:

(1) Warmup, which has pretest exercises and an Explanation mode with embedded questions.

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(2) Roll Call, in which the student matches terms to their definitions or vice-versa, in a game format.

(3) Target Practice, in which the student identifies items in a picture or answers various questions about a pictured scenario, in a game format.

(4) Mine Field, which reviews step-by-step job procedures and provides drills in a game format.

The first three of these, with some modification, are carryovers from the original Tutor prototype. The fourth, Mine Field, is a new routine designed to enhance job procedural training. In the original Tutor, only the picture game had a gaming feature. In CHIP, all but the Warmup include game features.

Courseware for various training applications is typically divided into 30 to 40 lesson segments, with a segment typically giving 10-20 minutes of instruction. Each lesson segment uses those routines that are applicable to its subject matter content. Every segment uses the Warmup component, plus at least one gaming routine.

The instructional routines were designed to incorporate proven cognitive principles for training job skills. Warmup instruction is presented mainly through the book, first with a series of Warmup questions that use the principle of delayed feedback. These exercises are followed by illustrated tutorial material which contains embedded questions that provide immediate feedback. The questions may be either contained in the book or presented by CHIP. Inclusion of a gaming feature in the Warmup component was ruled out because of indications from research (Malone, 1981) that gaming features, though useful in drills, could distract from the initial explanation process. The Minefield routine makes allowance for the fact that in some procedures, any of two or more steps might be equally correct at a given point. The routine also distinguishes between main steps and substeps of a procedure, to promote learning of the procedure in organized "chunks" (Smith & Goodman, 1984).

The Roll Call routine was designed so that each missed item is repeated two and then four items later. This increasing ratio review technique has been demonstrated to improve the transfer of information from short-term memory to long-term memory (Siegel & DiBello, 1980).

To accommodate individual differences in ability and to provide further challenge to students once proficiency has been achieved, each instructional routine (with the exception of Warmup) has both a basic level and an advanced level. The advanced level differs from the basic level principally by the imposition of a time limit and (for two of the routines) by the requirement that the student respond "YES" or "NO" to each answer choice, in turn, as it is presented.

During all training routines, students are given informative feedback about the correct answers -- a demonstrably effective instructional feature (Gagne & Briggs, 1979). An Erase key lets students erase and change an answer before pressing the Go key to enter it. A Say key lets students hear selected words pronounced at any point in the instruction.

Students have control over the order in which they work on lesson segments and on the order in which routines within the segments are attempted. They are given feedback about which routines and segments they have completed successfully. An advantage of giving students control over study components is that it is likely to increase intrinsic motivation (Kellar, 1983). Students can advance at their own pace and can over learn if necessary by repeating of segments.

Gaming Features

The design of the gaming formats built into CHIP's instructional routines draws on what makes research into video games interesting and motivating (Bobko, Bobko & Davis, 1984; Malone, 1981). Variables correlated with game popularity include scoring, audio effects, randomness, and graphic effects in Malone's (1981) research; and destructiveness, dimensionality, and graphic quality in Bobko et al's (1984) research.

Based on this research, the game formats in CHIP all present substantial graphic and audio effects after every response. The formats have well-defined goal structures that are displayed on the screen. The scoring of performance in each routine supplements these graphic effects. Although randomness is not a strong component to the routines (except for the selection of distractors to be included in questions, and in some cases the sequence of the questions), the advanced game formats in the CHIP routines do use time pressure, which Malone (1981) has suggested can increase the challenge of tasks.

Specific gaming features chosen for implementation in CHIP are described below.

Mine Field, to train procedures. In this routine, footsteps are displayed progressing safely through a mine field for correct answers to procedural steps. Correct answers are chosen by pressing the YES key when the correct step is displayed on the screen. (Choices, including correct steps, incorrect steps, and unsafe steps, are displayed one at a time in pseudo-random order.) Selection of an incorrect, but not unsafe, step causes the footstep to step sideways, and require the student to repeat the step correctly; too many such errors results in failure, ending the game. Selection of an unsafe step causes the foot to step on a mine, ending the game with an explosion. Either type of failure branches students to a Job-Step Review routine before they can attempt the game again. Successful completion of the game entitles the student to clear the mine field by setting off some or all of the mines—some, if his performance was less than perfect; all, if it was perfect. Thus, feedback for failure (an explosion) is no more interesting than feedback for success.

This game format was considered optimum for training job procedures because most (although not all) procedures do involve sequences, some of which are safety related or otherwise especially critical.

Roll Call, to train words-and-definitions. The performance objective is to correctly match ten consecutive words to their definitions, or vice versa. As in Mine Field, the student responds by pressing "YES" when the correct choice is displayed on the screen. The ten-question trials, with the words randomly

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rearranged, repeat until the objective is met. From the gaming standpoint, the objective is to build on the display screen a formation of 10 soldiers, as at morning muster. With each correct answer, CHIP's audio component responds with "Here, Sir" and adds one soldier to the displayed formation. With each incorrect answer, CHIP responds "Missing" and displays a blank slot in the formation. In keeping with the analogy, CHIP speaks "All Present, Sir" if the student scores 100% on a trial.

Target Practice, to train picture or parts identification. The Hand-Held Tutor featured a "friendly" projectile which progressed one direction with each correct answer and an "enemy" projectile which progressed the opposite direction with each incorrect answer, both on the same line. In CHIP, taking advantage of the multi-line display capability, the projectiles travel in a trajectory rather than a straight line; the friendly and enemy guns, as well as the projectiles, are displayed; and a new projectile is fired upon each response, its distance depending on the cumulative number of correct and incorrect responses. A sample screen and book page for Target Practice can be seen in Figure 3. In this routine, the student responds by pressing letter and/or number keys, depending on the question.

Courseware Applications

CHIP software is suited to a variety of curricula, such as occupational specialty training, common task training, math skills, language instruction, and hazardous procedures training. Six Courseware applications were developed for the test phase of CHIP.

- Chaparral Crewman Operations (Army)
- Vehicle Recovery Procedures (Army)
- Celestial Navigation (Navy)
- M-60 Machine Gun Operations (Air Force)
- Ordnance Recognition and Safety (Inter-Service)
- Basic Math and Problem Solving for combat engineers, for the 7ATC NCO Academy (US Army Europe)

TEST AND EVALUATION

Framework for Evaluation: Uses, Conditions, Environments, and Alternatives for CHIP Training

CHIP was originally intended as a sustainment trainer for use in the field during lull time. As the services became involved in project planning, they identified uses for CHIP in the school: to supplement classroom training, to remediate failing students, and to shift some portions of initial classroom training to a computer. In all cases, CHIP was conceived as an adjunct to hands-on performance, to classroom lecture, or to sophisticated computer instruction, and not as a stand-alone trainer or a primary conveyor of initial training.
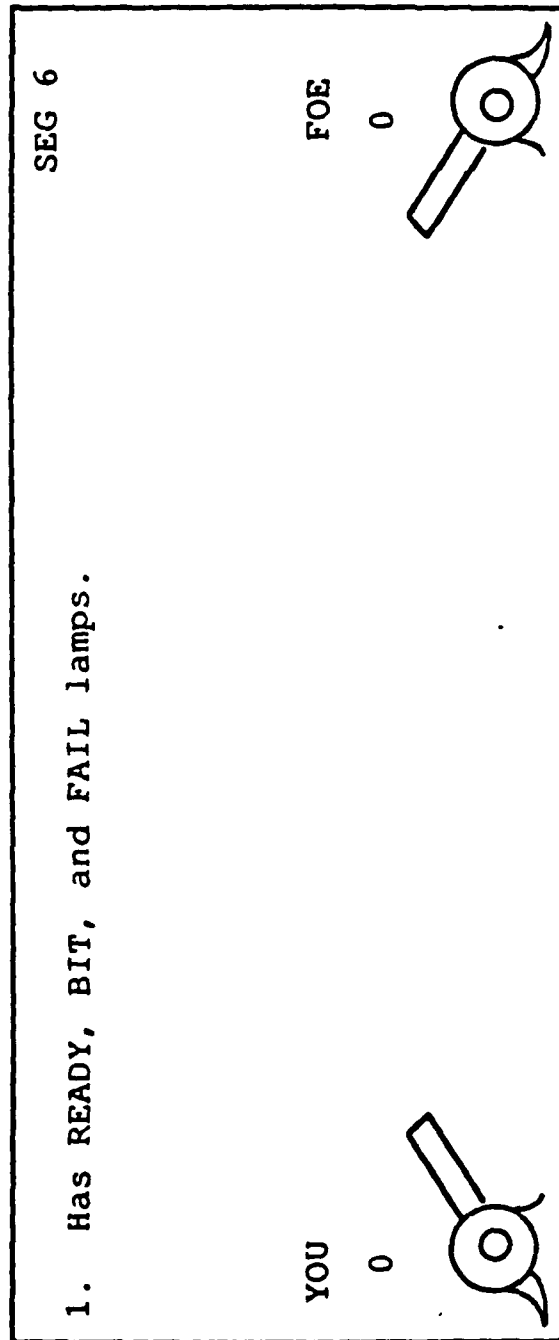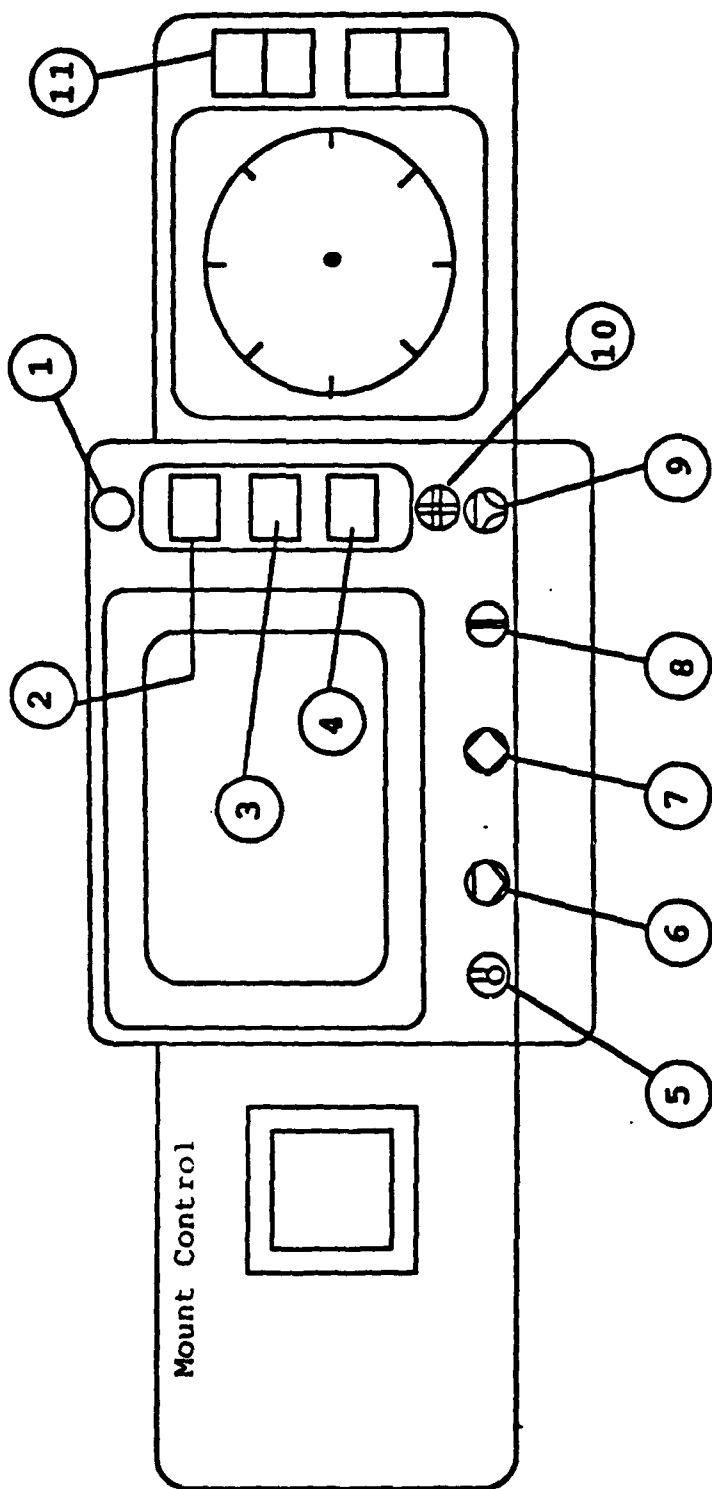
CHIP TARGET PRACTICE

Mount Control

SEG 6

FOE

0

YOU

0

1. Has READY, BIT, and FAIL lamps.

Figure 3. Sample screen and book page from Target Practice

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The CHIP evaluation tested each of the uses identified by the services, defined as follows:

Initial training - Provided to a student for the first time on a particular topic.

Supplemental training - Designed to reinforce or enhance initial training.

Remedial training - Provided to a student who is experiencing learning difficulties.

Refresher training - Designed to reclaim skills or knowledge lost or diminished by lack of practice or use.

This range of uses was judged important to test given the demonstrated influence of context and purpose on the effectiveness of training devices. Moreover, given the history of extension training materials like TEC tapes, which have shown unexpectedly low rates of application, (General Accounting Office, 1985) it was judged necessary to observe usage patterns of CHIP under the voluntary conditions characteristic of lull time. Therefore, training conditions were defined as either mandatory, scheduled, and instructor-supervised, or as voluntary, unscheduled, and unsupervised, and this dimension was included in the evaluation. The voluntary condition is referred to here as opportunity training and defined as follows:

Opportunity training - Unscheduled and acquired by students who take advantage of lull time in areas not designated for training. (Opportunity conditions can occur for any of the four training uses listed above but are more likely to occur for supplemental or refresher training.)

In addition, CHIP was designed to train in a number of environments: for mandatory training, mainly in classrooms and study halls for opportunity training, in and outdoor or field settings, day rooms, barracks, recreation areas, and vehicles or aircraft (during transport). The significant environmental factor was felt to be indoor vs outdoor use because of the different stresses each places on equipment.

Finally, as a medium for simple instructional functions, CHIP can be compared with a number of training alternatives: technical manuals (TMs), field manuals (FMs), or other paper-based material; an instructor's lecture or tutoring; and sophisticated computer-based instruction such as Interactive Video Disc (IVD) or simulation.

We felt that these dimensions - training uses and conditions, environments, and instructional alternatives - were likely to make a difference for training effectiveness of the hand-held prototype. The evaluation design included all the defined uses and conditions and sampled the possible environments and alternatives. These dimensions were combined opportunistically across test sites, depending on local needs and constraints, rather than being systematically varied to yield every possible combination of values. Schools and agencies at participating sites made final decisions on how they would test CHIP. The uses, conditions, environments, and alternatives

chosen for each CHIP application can be seen, among other evaluation dimensions, in Table 1. (Note that under "Uses and Conditions," training is considered to be mandatory and scheduled unless indicated as "opportunity training.")

Evaluation Sites

As shown in Table 1, six sites were included in the CHIP evaluation. These sites employed CHIP in five different curricula, paired as follows:

1. U.S. Air Force Combat Arms School, Lackland Air Force Base, Texas: M-60 machine gun operations

2. U.S. Navy Quartermaster "A" School, Orlando, Florida: Celestial navigation

3. U.S. Army Ordnance Center and School (USAOC&S), Aberdeen Proving Ground, Maryland: Vehicle recovery procedures

4. U.S. Army Air Defense Artillery School (USAADASCH), Ft. Bliss, Texas: Chaparral crewman operations

5. U.S. Army 1-67 Air Defense Artillery Battalion, 9th Infantry Division, Ft. Lewis, Washington: Chaparral crewman operations (Identical to #4)

6. Inter-Service Explosive Ordnance Disposal School (EOD), Indian Head, Maryland: Ordnance disposal & reconnaissance procedures

A sixth CHIP curriculum - on basic math and problem solving for the Army combat engineer (MOS 12B) - was applied at the 7ATC NCO Academy, Hohenfels, Germany, without formal evaluation.

Evaluation Results

This section summarizes the evaluation environment, uses, alternatives, and results from the first five test sites. This summary is not intended to provide details about the use of CHIP by subjects at each site nor about the established procedures employed to evaluate group difference at each site. These details may be found in the separate reports provided by each test site (NTSC 1987; Eagle Technology 1987; ASA 1988a, b, c). In addition, a complete account of test designs, rationale, evaluation criteria, and critical test issues appears in the CHIP Test and Evaluation Master Plan (Holland, Noss, and Oxford, 1988). The test at EOD concluded late and has been prepared as a separate report (Evans, forthcoming).

Table 1 identifies four applications that used a 2-group comparison of CHIP with the existing training procedure. The remaining two applications used a 3-group comparison of CHIP with existing and alternative training procedures. At each test site one or more measures of training effectiveness was collected. The design, measures, and types of subjects varied from site to site. At the conclusion of the evaluation for each application, experimental group

Table 1: CHIP Evaluation Elements

Sites	Uses and Conditions	Environment for CHIP Use	OPERATIONAL EFFECTIVENESS MEASURES A. Relative Effectiveness of a Training Device. B. Relative Reduction of Attrition/Roll-Backs C. Relative Reduction of Instructor/Student Time	TEST DESIGN		Sample Size and Characteristics	*Key Audiences
				2 Group Quantitative Comparison	3 Group Quantitative Comparison		
U.S. Army Air Defense Artillery School (USAADASCH) Ft. Bliss, TX	Supplemental Training, Opportunity Training	Classroom, Study Hall	A	A. Voluntary CHIP B. Voluntary Technical/Field Manuals	—	16P Students 32 in CHIP Group 42 in Control Group	USAADASCH PM TRADE TRADOC HQ ARI
Field Site: Ft. Lewis, WA	Supplemental Training, Refresher Training	Classroom, Outdoor Opportunity Areas	A	A. CHIP B. Instructor and Technical Field Manuals	—	16P's On-the-Job, 20 in CHIP Group 22 in Control Group	USAADASCH PM TRADE TRADOC HQ ARI
Army Ordnance Center and School (USAOC & S) Aberdeen, MD	Initial Training	Classroom, Outdoor Opportunity Areas	A	A. CHIP B. Instructor, Study Guide, and Technical/Field Manual	—	Random Assignment to Groups; Use 63W Trainees, 30 Students Per Group	USAOC & S PM TRADE TRADOC HQ ARI
Navy Quartermaster "A" School Orlando, FL	Remedial Training	Study Hall	A,C	A. CHIP B. Instructor and Workbook	—	Quartermaster Students Who Have Failed Units 5, 11, and 12; 30 Students Per Condition	TPDC CNET CNTT NAVTRASYSCEN NPRDC NTC
Air Force Combat Arms, Lackland AFB, TX	Supplemental Training,	Study Hall	A	—	A. CHIP B. Self-paced Test C. Study Guide	500 Security Police Students Attending M-60 Machine Gun Training (300 in Nonspecialist Course, 200 in Specialist Course)	ATC AFHRL AFOSP
Interservice Explosive Ordnance Disposal School (NAVSCOLEOD), Indian Head, MD	Supplemental Training	Study Hall	A,B,C	—	A. Workbook B. Voluntary CHIP C. Mandatory CHIP	150 EOD Students (75 for Voluntary CHIP Group, 75 for Mandatory CHIP Group)	NAVSCOLEOD NAVTRASYSCEN CNTT PM TRADE TRADOC HQ

*Appendix B Provides a Glossary of Acronyms

participants reported their reactions to CHIP on one of two questionnaires designed to assess impressions of the suitability of the device for training, availability, maintainability, and supportability. A student opinion questionnaire gathered reactions from students in the experimental group and, as a control, assessed their attitudes toward computer-assisted learning. An instructor questionnaire gathered reactions from instructors and supervisors, including identification of problems with CHIP.

M60 Machine Gun Training. U.S. Air Force Combat Arms School, Lackland Air Force Base, Texas

Application. The objective of the Combat Arms School was to test CHIP's capacity to supplement classroom instruction for M-60 machine gun operations, given current limitations in classroom time. The Air Force Military Training Center (AFMTC), which oversees the CHIP test and evaluation at Lackland AFB, evaluated specialist and nonspecialist students using one of three training routines: CHIP, existing M-60 reference manual, and a self-paced text that was essentially a paper version of CHIP (multiple-choice, drill-and-practice routines without audio/video features or interactivity). M-60 courseware included assembly, disassembly, malfunctions, fire-control, and range cards. The Air Training Command at Randolph Air Force Base, Texas, sponsored this application.

Environment. Classroom, used as study hall.

Use of CHIP. To provide supplemental training in support of regular classroom training.

Alternatives. Paper-based hardcopy of CHIP curriculum and standard United States Air Force (USAF) M-60 Handout (a reference manual).

Major Results and Discussion

Opinion Questionnaire. Nonspecialists gave CHIP a mean rating of "satisfactory", whereas specialists on the average rated it as "OK" (neutral). A possible explanation for this disparity emerged in the ratings given CHIP's specific aspects: Specialists had a much greater tendency than nonspecialists to say they got tired of CHIP and found it unmotivating. This may be because specialists, who are more advanced, desire to move faster through a curriculum than is allowed by the incorporation of gaming features and non-branching exercises such as found in CHIP.

Performance Evaluation. A specially designed written test was given at the end of the study, consisting of fill-in-the-blank and short answer items designed to assess knowledge of the M-60. Mean test scores were low (below 48 percent correct) for all groups. There was no statistically significant difference in mean test scores, corrected for differences in aptitude, between the CHIP and control groups.

Conclusions and Qualifications. While the CHIP group appeared to perform no better than the control groups, this finding must be interpreted in light of several constraints on the study: probable low incentive in all groups, an

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unusually brief evaluation period, and written test difficulty. These factors may have obscured any performance differences between the groups that would have otherwise been demonstrated, as discussed.

Low incentive may be inferred from the fact that students had just graduated from the M-60 course. Thus, they had little reason to study the material attentively or to do well on the test. This may account for why all groups tested poorly.

Students were given very little time on their respective study materials (two two-hour sessions). Moreover, students were free to leave the study hall when they felt they had studied enough, and many students were observed to leave well before the session ended. The amount of time given and spent may have been insufficient to reveal differences between treatments.

The written test content, specially designed by instructors for this study, may have been too difficult to detect differences between treatments. Instructors tended to score this test conservatively, requiring exact answers on fill-in-the-blank and short answer items.

Given these qualifications, the results of the Air Force test must be viewed as equivocal.

Quartermaster "A" School Training. U.S. Navy Quartermaster "A" School, Orlando, Florida

Application. The objective of the Navy application was to assess CHIP as a means of remedial training for Quartermaster students who failed some units of classroom instruction in celestial navigation. Failure rates in the course were highest in areas requiring application of math operations to charts or tables. A driving question was whether CHIP could reduce the instructor's intensive contact time with remedial students, freeing instructors for needed administration tasks. In addition to remedial training, the school felt that initial training of absentees on sick leave represented a potential use for CHIP, although this use was not included in the evaluation. Key topics in the CHIP courseware included computation of gyro error by azimuth, time and time zones, arc/time relationships, calculation of sunrise and sunset, time/speed/distance, and dead reckoning.

Environment. Night study hall.

Use of CHIP . Remedial training.

Alternative. Existing workbook plus instructor as tutor (Average ratio was one tutor per four (4) to five (5) students). As is conventionally done in night study hall, the instructor monitored students working in the workbook and tutored individually as needed. An instructor was also present in the CHIP group to monitor students. No constraints were put on this instructor—that is, he or she was free to interact with students as deemed necessary.

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Major Results and Discussion

Opinion Questionnaire. The majority of both students and instructors rated CHIP as a "satisfactory" to "excellent" method of instruction. While instructors rated CHIP favorably, they indicated a preference for the traditional workbook instruction employed in the control group.

Performance Evaluation. The chief measures of training effectiveness were (1) the gain between pre- and post-test scores (using the existing end-of-annex exam as a post-test) and (2) the number of rollbacks. No significant difference in test performance or rollbacks was found between the control and CHIP groups. A third measure of effectiveness was the amount of contact time between instructor and student, with less contact time being an indication of effectiveness. There was a trend towards reduction of instructor-student interaction time in the CHIP group. The average instructor interaction time was 13 minutes per hour for the control group, and eight minutes per hour for the CHIP group. However, the reduction in instructor time for the CHIP group did not achieve statistical significance.

Conclusions and Qualifications. Students using CHIP performed as well as, but no better than, the control group. There was a trend indicating that CHIP reduced instructor-student interaction time. One reason this trend failed to achieve statistical significance may be that instructors were not inhibited from contact with students in the CHIP group.

Observers of the study noted that instructors felt it was their job to check on students, and that much of the recorded instructor-student interaction time in the CHIP group involved instructors asking students if they needed help rather than actively providing help. These observers officially recorded only the number and duration of contacts during randomly selected time samples, not the substance of a contact. A fairer assessment of whether CHIP could reduce instructor time might be obtained by removing the instructor, controlling instructor contact, or by recording the qualitative nature of the interaction. Thus, the results of this evaluation suggest that CHIP may reduce the amount of expensive instructor time required in a training program, a possibility that warrants more controlled assessment. The following conditions should also be considered in interpreting the results of this evaluation:

There appeared to be insufficient time to complete material using CHIP. The CHIP group took longer per unit of instruction than the control group. Thus, the CHIP group may have had insufficient time to complete curriculum segments and to repeat exercises. Because students in the CHIP group took longer to complete exercises, they were instructed to ignore several course segments that the instructors felt were not critical to performance on the test. The CHIP group performed as well, or better than, the control group on the segments they had time to complete. Projected calculations based on the number of segments completed in a unit and the test score for each unit indicate that significant increases in end-of-annex test scores may have been achieved by the CHIP group if time had permitted students to complete all segments.

A disadvantage for any kind of computer-based instruction lies in presenting spatially extensive material such as maps, charts, and flow diagrams. The control group, using workbooks, had the benefit of specially prepared, large-scale foldouts which may have helped them with chart and map-reading exercises.

MOS 63W10 Wheeled Vehicle Maintenance Training. U.S. Army Ordnance Center and School (USAOC&S), Aberdeen Proving Ground, Maryland

Application. The objective of the USAOC&S application was to determine whether CHIP could effectively provide initial training, replacing lecture, for selected aspects of vehicle recovery operations: the practical use of physics, including calculations of weight, resistance, force vectors, and mire factors. This application is an instance of "curriculum shift." Students receiving CHIP instruction were MOS 63W10. The findings were expected to generalize to MOS63H10 students, who are taught the same vehicle recovery content.

Environment. Classroom.

Use of CHIP. Initial training. (CHIP replaced an instructor for training on selected new material.)

Alternatives. Instructor providing lecture and using overhead transparencies, flipcharts, chalkboard.

Major Results and Discussion

Opinion Questionnaire. The majority of the CHIP students (over 70%) gave the device an overall evaluation of "satisfactory" to "excellent". About one-fifth gave an overall evaluation of "unsatisfactory" to "poor".

Instructors were generally favorable, with the majority giving an overall evaluation of "satisfactory" or "OK".

Performance Evaluation. The primary measure of training effectiveness was scores on the end-of-annex written test of vehicle recovery knowledge. Both groups demonstrated sharp increases in learning compared with a knowledge pretest. There was no statistically significant difference in performance scores between the groups; however, the control group showed a trend toward higher scores. This trend was not surprising in that an instructor is expected to be more effective than CHIP for initial training.

Conclusions and Qualifications. This evaluation was perhaps the most stringent test for CHIP. First-exposure, stand-alone training is more complex than supplemental training, and usually requires software sophistication that was not built into CHIP. Nevertheless, CHIP students performed as well as the control group. Note that the CHIP curriculum on vehicle recovery was not originally designed for initial training, but rather for supplemental and opportunity training. Subsequent judgement by instructors that the CHIP material was very similar to the lecture material led USAOC&S to change the purpose of CHIP to initial training.

In this evaluation, the results suggest that use of CHIP may lower overall instructor costs by reducing instructor time required for some aspects of a course.

MOS 16P Chaparral Training Program. U.S. Army Air Defense Artillery School (USAADASCH) Ft. Bliss, Texas

Application. USAADASCH is the Army proponent school for CHIP development and testing. The school's objective was to determine whether CHIP could improve instruction on the Chaparral surface-to-air missile system: in particular, whether CHIP could be used opportunistically and effectively by Military Occupational Specialty (MOS) 16P students during the long waiting periods that are part of practical hands-on training exercises. Topics covered in this application related to the component of the Chaparral forward looking infrared (FLIR) and included control panel overview, reticle patterns, optical sight, hand controls, identification friend or foe (IFF) tones, air defense warnings, engagement communications, and fire decisions. The IFF tone instruction provided a test of the audio feature of CHIP for non-speech sounds.

Environment. Lull time that accompanies outdoor practical exercises. Lull time occurs because of the high ratio of students to equipment. Students may wait hours to get hands-on practice on the Chaparral. The school intends students to use waiting periods to study relevant technical and field manuals.

Use of CHIP. Supplemental training. Voluntary use of CHIP and alternative materials.

Alternative. Existing technical and field manuals for MOS 16P.

Major Results and Discussion

Opinion Questionnaire. CHIP was very well received. An overwhelming majority of students gave CHIP an "excellent" or a "satisfactory" rating; the lowest rating (one student) was "OK". Of the instructors two (2) rated it as "excellent", and the third as "OK".

Performance Evaluation. The measure of training effectiveness was the mean score on the end-of-annex test for the FLIR portion of the Chaparral crewmen course. This test was particularly difficult, with a lower pass rate than other annex tests, resulting in high attrition costs. The mean score for the CHIP group was significantly higher than the control group, a difference of nearly 10 points.

Conclusions and Qualifications. Potential benefits of CHIP suggested by this evaluation are an increase in annex pass rate and a consequent reduction in attrition-related costs to the school. This benefit is achieved without increasing existing classroom or instructor time.

Limiting these findings is a time-on-task factor. Observers noted that the CHIP group spent more time studying than the control group. Thus, the inherent training effectiveness of CHIP is confounded by the increased motivation it appeared to impart, which led to more study time. Nevertheless, the

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theoretical separation of these two factors is of little practical concern to USAADASCH. The school's driving question was whether test scores on FLIR could be improved without extending classroom time.

Another limitation of the findings is the novelty factor. Would CHIP continue to motivate students to study voluntarily beyond the first few days of receiving it? (The test period was three days).

FLIR Concepts for Chaparral Weapons System. U.S. Army 1-67 Air Defense Artillery Battalion, 9th Infantry Division. Ft. Lewis, Washington

Application. A field evaluation of the Chaparral curriculum used at USAADASCH was conducted at Fort Lewis in coordination with the 1-67 Air Defense Artillery Battalion of the Ninth Infantry Division Motorized. The objective of the Fort Lewis study was to evaluate CHIP in a field setting to determine its effectiveness for refresher/sustainment training. To accommodate prevailing conditions at Fort Lewis, the evaluation took place in garrison during training time with members of Delta Battery, 1-67 Air Defense Artillery Battalion.

Environment. A classroom set-up.

Use of CHIP. Refresher training.
Alternative. Two instructors providing specially prepared, interactive lecture and instruction.

Major Results and Discussion

Opinion Questionnaire. The majority of soldiers (85%) rated CHIP as either "satisfactory" or "excellent". The instructors also rated the device favorably. They reported no equipment problems and judged that the medium and the lessons were valuable.

Performance Evaluation. Soldiers in the CHIP group and the control group were matched on prior knowledge of FLIR as measured by a pretest. Both groups demonstrated sharp gains in knowledge on a specially designed multiple-choice post-test. The control group achieved significantly higher gains than the CHIP group.

The CHIP group required virtually no instructor time, while the control group involved two instructors, one of whom was in constant interaction with students.

Conclusions and qualifications. Although the control group improved significantly more than did the CHIP group, it should be noted that instructors knew they were participating in an experimental study. Consequently, they designed a dynamic ad hoc course that involved interchanges with all students - a highly advantageous form of training.

Since both groups showed large knowledge gains, this study suggests that significant savings in instructor time can be realized by employing CHIP as a training aid. The somewhat greater gain found in the control group (26% vs 17%) resulted from a considerable expenditure of instructor resources, both in preparation of material and in training time.

CONCLUSIONS AND RECOMMENDATIONS

GENERAL EFFECTIVENESS

Covering a range of applications, the CHIP evaluation data suggest that CHIP's effectiveness as a training aid depends on (1) the nature of the alternative, (2) the level of the student, (3) the presence of incentive, and (4) the nature of the subject matter.

First, CHIP produces the best results when used as it was intended: as a voluntary trainer to supplement lecture and practical exercise during lull time outside the classroom. Under these conditions, instructor tutoring and traditional computer instruction are impractical and the only realistic alternative is paper-based material- to which CHIP appears generally superior. CHIP's suitability for lull time conditions lies in its portable dimensions, durable hardware, and battery operation. Under classroom or study hall conditions, when the alternative is an instructor providing lecture and tutoring, our data indicate that CHIP trains no better and may train worse. This is not surprising given the body of findings that CAI in most forms cannot compete with teachers. Unlike a computer program, a teacher can deal flexibly with curriculum complexities, understand novel questions, recast explanations, and branch to new combinations of information as needed.
Second, CHIP yields the best results with students who are subject matter novices, getting their primary introduction to the subject by an instructor. When CHIP users are advanced and current in the curriculum, as opposed to novices or to past graduates who need refresher, they appear to respond less favorably to CHIP. Anecdotally, some advanced students reported that the gaming features of CHIP impede the pace of instruction and that the linear structure of the exercises - with little branching and no early exit - forces them to traverse material they already know. These students preferred methods that allow more flexibility in moving through explanation and exercises.

Third, the best results come from students who have a meaningful goal that makes CHIP's utility apparent - like passing end-of-course exams or Skill Qualification Tests (SQTs). When usage is not tied to an incentive of consequence, CHIP, like other media, tends to be neglected and/or to produce negligible knowledge gains. Even when the incentive is mild - doing well on a test for which other training is already provided - CHIP appears to be more motivating than paper-based materials, more heavily used, and more effective. CHIP's motivational advantage over paper appears to lie in its game-based format with animated graphics. Its instructional advantage is inferred to lie in the immediate delivery of feedback, the dual coding (audio and visual) of information, and the memory-enhancing structure if its drills (as described earlier).

Finally, CHIP works best for subjects requiring memorization of facts and terms, quick identification of auditory patterns or visual features (in line drawings), and fluency in simple math, physics, or engineering facts and formulas. CHIP works less well than paper supplements for training use of spatially extensive materials like flowcharts, functional block diagrams, and large-scale maps. CHIP is inappropriate for tasks requiring psychomotor coordination or requiring integration of complex variables in problem-solving.

To make recommendations from these results, the tested effectiveness of CHIP must be weighed against cost. Since CHIP costs more than a manual to produce and maintain, it is expected to train better than a manual to warrant its cost. CHIP's superiority to manuals emerges most saliently under voluntary use and opportunity conditions, with students who are at an appropriate level to gain from drill and practice and who have some imminent reason to study. The fact that under these conditions CHIP requires no increase in classroom or instructor time strengthens its potential cost effectiveness, as these cost elements would not be factored.

On the other hand, CHIP costs less than an instructor and less than a desktop computer, an IVD system, or a simulator. If it trains as well as or nearly as well as these alternatives for certain subjects, than it should be cost effective in those subjects. CHIP is found equal or nearly equal to instructors for drilling basic math or physics facts, job-relevant vocabulary, and picture/parts identification. CHIP thus appears to be a cost-effective trainer for these subjects even during scheduled training time and in classroom settings. CHIP's cost advantage over other computer media, which are also less expensive than an instructor, lies in its limited size, screen, and keyboard and its simple software, designed for multiple-choice, fixed sequence exercises and for easy authoring. The actual determination of CHIP's cost effectiveness, of course, depends on the circumstances surrounding its use. This determination should be made as part of a cost-training effectiveness analysis prior to an implementation.

Specific Features

CHIP was well received by students and instructors. Ratings of individual features of CHIP on the opinion questionnaires followed the same pattern as the overall ratings, i.e., generally favorable.

The hardware seemed to work reliably, with the exception of a reported problem with rapid battery drain in a few devices. CHIP was viewed as easy to set up, and the screen easy to adjust and see. The keys were reported to be easy to find and use, the words on the screen easy to read, and the speech clearly audible. A formal human factors evaluation of the device confirms these subjective ratings. This evaluation indicated one potential problem: users who had a flat surface on which to lay CHIP did not take advantage of the thumb key arrangement, but used their fingers for all keys. A possible re-design with response keys in the center was recommended if CHIP is intended largely for indoor, classroom use.

CHIP was found to make relatively low resource demands and require minimal instructor assistance. The hardware costs are expected to be about $200 per unit, and an MS-DOS-based authoring tool minimizes courseware development time.

The authoring tool is described in a separate authoring guide (Krug International, 1987). With the use of this tool, courseware development is expected to cost about $30K for 15-20 hours of instruction, including development of new digitized speech. If the curriculum requires heavy front-end analysis, the cost is expected to be higher. If the curriculum is well-defined and has structured materials available from which CHIP exercises can be

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extracted, then development costs are expected to be lower. These issues, andthe suitability of CHIP for particular kinds of courseware content, are discussed in Oxford, Holland, & Goble (1987).

STATUS

The Training Device Need Statement submitted for CHIP by USAADASCH was formally approved by TRADOC in 1987. However, the course of acquisition is delayed because of funding limitations. CHIP continues to be used for local training needs by many of the original test participants, and is being demonstrated in several additional schools and agencies across the services and outside of DOD. The final distribution of CHIP units and courseware is shown in Appendix H.

COMMERCIALIZATION

Civilian agencies and the private sector are expressing an increased interest in the application of defense developed technology to the solution of their problems. Congress has recognized the value of transferring the benefits of federally-funded research and development to the civilian and private sectors through the enactment of the Stevenson-Wydler Technology Innovation Act of 1980, Public Law 96-480, and its amendment, the Federal Technology Transfer Act of 1984 (Public Law 98-620). Executive Order 12591 of April 10, 1987, served to ensure that Federal Agencies and laboratories assist the private sector in broadening the nation's technology base by moving new knowledge from the laboratory into the development of new products. In accordance with section II, PL 96-480, the Army has continuing responsibility to insure the full use of the results of its investment in R&D. The Army is also required to actively promote and encourage the appropriate transfer of Army-originated technology to state and local governments and the private sector.

In accordance with PL 96-480, Army Regulation 70-57 prescribes responsibilities and policies for active technology transfer to the civilian and private sectors. Within ARI, an Office of Research and Technology Applications (ORTA) was established to centralize coordination for technology transfer activities. The ORTA, then, serves as the focal point for the transfer of the CHIP technology.

Interest in the hand-held training technology began during public demonstrations of the Tutor. In August 1984, in Albany, New York, the tutor was demonstrated to the Council of Chief State School Officers. The Council responded favorably to the advantages of such a technology for use in public education. They were particularly attracted to the portability and projected low cost, but frustrated by the lack of commercial availability. The civilian and public sector interest in the hand-held training technology continued with the introduction of the CHIP, which was demonstrated at several professional and public events, including to members of Congress in June 30, 1987 at the request of the Congressional Clearinghouse for the Future. The Adult Literacy and Technology Institute, Pennsylvania State University, was especially interested in the prospects of CHIP to help remedy the significant national problem of adult illiteracy. Dozens of written requests by public and private institutions that provide adult literacy training were received by ARI. These

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institutions were mostly interested in how they could acquire CHIP and orientit towards adult literacy training. These interests were relayed to the ARI ORTA.

The ORTA invited the developer of CHIP, who had since changed their name to Krug International, to enter into a Technology Transfer Agreement in accordance with Public Law 98-620. The principal issues that were recognized while working towards a negotiated agreement were the ownership of the tooling, ARI's role in pursuing potential government and non-government markets, the Krug International investment in value engineering to further improve the product, the establishment of firm unit prices for various quantity ranges, and the availability of CHIP as an off-the-shelf product. These issues, and others, are the subject of review as of the date of writing this report.

The military serves to benefit directly from such a commercialization. The availability of CHIP as a commercial-off-the-shelf product follows the growing procurement practice of hardware acquisition through the purchase of non-development items. Through technology transfer, CHIP would transition from a prototype to a manufactured item at no additional cost to the military. Such an arrangement would provide rapid access to the product, which otherwise would be longer due to lead times for parts and start-up times for production and assembly. A cost advantage could also be realized through the economies of scale --a large civilian purchase could reduce margin costs for additional units. These benefits, of course, depend on a successful transfer of the technology, so it is not possible yet to determine the potential reductions in time or cost. The transfer is still being negotiated.

LESSONS LEARNED

Management

The size of the CHIP development and test effort -- 250 devices, 7 sets of courseware, and 6 test sites coordinated across 3 services -- was too massive for efficient management by a single project officer. Without staff, the project experienced schedule slippage, data losses, and gaps in promoting and publicizing CHIP to appropriate users across the services. For future efforts of this kind, it is recommended that either the project scope be reduced - for example, 2 services with 50 devices - or that additional staff be provided - at minimum, an educational specialist, an electrical or mechanical engineer, and an administrative assistant or accountant.

Technical

Alternatives to the CHIP's physical design should have been a contractual requirement. This might have reduced the somewhat bulky appearance, and reduced the weight to a more comfortable level.

Testing

CHIP should have been evaluated for uses closer to the intended one -- as a training supplement during lull periods, rather than as a general device for

training delivery. In view of the limited management resources to oversee the evaluation, the tests should have focused more on CHIP's use during opportunity training.

Joint Services

The working arrangements between the lead and participating services lacked the forcefulness that might otherwise occur within a single service. For example, the unexpected allocation and reassignment of personnel from a participating service during the project increased the demands on the project manager to meet contractual and test schedules. Such changes might not have occurred, or at least not as frequently, if the project manager had more direct control over the personnel assets. Although letters of agreement between the respective parties were signed, they lacked provisions for priorities in personnel assignments, duties, and accountability. These provisions could have been included in an annex to the general agreement. Another means of elevating the priority of the project for a participating service would have been to cost share more of the effort thus increasing the accountability of the participants. A cost share arrangement worked well with the Air Force in the case of CHIP.

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